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著者	Nishi Tokumichi
journal or publication title	Tohoku psychologica folia
volume	17
number	1
page range	1-20
year	1958-11-10
URL	http://hdl.handle.net/10097/00127224

A NEW TENTATIVE THEORY OF VISUAL SPACE PERCEPTION (II)

by

Tokumichi Nishi (西 徳道)
(Institute of Psychology, Iwate University, Morioka)

In the first part of this paper, chiefly the phenomenal facts concerning the visual space perception attached importance to 'depth limit' have been described.

Now the writer is intending to explain the data which corroborate those phenomenal facts in question, and to formulate exclusively special theory of his own concerning visual space perception, irrespective of many divergent views which should be criticized in order to advance his own theory, but commenting on a few of them at need.

RELATION BETWEEN RETINAL IMAGE AND PERCEPT

The core of the present theory consists of a special lecture on the subject of 'The Aspects of the Visual World' delivered at the Meeting of Association of Psychologists in Tohoku district in 1942, somewhat being complemented. The terms used in the present paper differ to some degree from those used in the lecture.

We are surrounded by tridimensional manifold of physical existences comprising visual space. We cannot perceive the physical existence directly. The physical existence must be only the source of stimuli, e.g. light waves which are radiated or reflected in all directions, and some of which are received by our retina and give rise to patterns of excitations, i.e. retinal images which finally produce percepts.

Koffka[18] has stated:"—the table in the geographical environment can be called a stimulus for our perception of a table; on the other hand the excitations to which the light rays coming from the table give rise are called the stimuli for our perception. Let us call the first the *distant* stimulus, the second the *proximal* stimuli".

The 'proximal stimuli' may be admissible, but the notion 'distant stimulus' seems certainly to have fallen into an error. For the table in the geographical environment is not a stimulus, but a percept. He has turned effect into cause. One of the tangible evidences that a table is a percept is the fact that it has a certain color or color manifold. Color is produced by perception, i.e. the psychological process, it is not an essential attribute of a physical existence. The physical existence is only the source of stimuli, the light rays, which may be converted into color perception, and can be recognized indirectly through an inference from the visual world.

So each world (physical or visual) belongs to quite a different system. There is, naturally, a certain close relationship between them. Especially, in a very short range of the observer, both physical and visual spaces coincide almost exactly, as will be fully explained later.

It's a knotty problem to elucidate the reason why such a state of affairs can occur. The writer begins by analyzing the prevailing views of visual space perception. They all acknowledge that the physical objects throw images on the retina two-dimensionally, and that in spite of the two-dimensional frame, they give rise to three-dimensional space spontaneously.

It was a common nineteen-century belief that as the retinal images are two-dimensional, so our space perception should be two-dimensional; our three-dimensional space perception is learned by experience. The Gestalt psychologists, on the contrary, claim that the visual space perception is three-dimensional from the outset in consequence of our innate tendency.

Both of them seem equally to base their views upon the 'projection theory' as all the other theories do. 'Projection theory' has been expressed satisfactorily by the following representative explanation of William James[16]: "This theory admits that each eye sees the object in a different direction from the other, along the line, namely, passing from the object through the middle of the pupil to the retina. A point directly fixated is thus seen on the optical axes of both eyes. There is only one point, however, which these two optical axes have in common, and that is the point to which they converge. Everything directly looked at is seen at this point, and is thus seen both single and at its proper distance".

It may be easily understood by above quotation and Fig. 55[14] that the meaning of 'projection' is of the physical action. The relation of a retinal image and the perception of the external object is left quite unnoticed notwithstanding its great importance by dismissing very lightly: "Everything directly looked at is seen at this point, and is thus seen at its proper distance." The cone of light rays which are radiated or reflected by a physical existence enters the eye and is focused as an image on the retina as is described clearly by the 'projection theory'. It is not likely that the retinal image itself directly gives rise to the visual space perception. The latter is produced through the highly complicated psychophysical mechanism and is an integral part of the whole process. Now the most important problem, that is to say, the relation between the retinal image and the percept, i.e. the visual space, must be taken into consideration. Thus far, any and every theory of visual space perception has never made researches on that relation scrupulously[a], though the foregoing Koffka's theory seems to have analyzed the existing views on this question. If the 'proximal stimuli' i.e. the retinal image, give rise to the perception, what connections they have with the 'distant stimulus', and vice versa.

When 'phenomenal regression to the real object' is applied to 'size constancy', you can interpret it that the perception caused only by the 'proximal stimuli' at an early stage of evolution, began to regress toward the real object, and in the course of evolution, the perception has come to be caused by the 'distant stimulus'[b]. Provided that 'phenomenal regression to the real object' has been realized, as Thouless[23] advanced, the 'proximal stimuli' may become quite useless. On the other hand, before the 'phenomenal regression' has began the 'distant stimulus' must be lacking, consequently lacking also three-dimensional visual space.

The visual organ can be construed into the whole complicated mechanism participating in vision including eye, centripetal and centrifugal nervous tissues, and the visual parts of the brain. This whole mechanism, the writer presumes, must be a special organ which has a force to 'project'[c] or localize the retinal image outside according to the multifarious conditions. These conditions are classified into two large groups. The one is the main factors and the other the secondary ones.

The main factors chiefly consist of variations in distance or length from O to the physical existence. Within a very short range of O, the 'projection' of the retinal image toward outside world is so exact that each 'projected' point of the image coincide with each corresponding point of the physical existence. That is to say, one can measure the depth accurately to a certain degree within a close proximity to O. But the so-called 'perceived distance' beyond some range of O may be vague, if it means 'directly' perceived absolute distance, because it is apt to be reduced to the subjective presumption. In other words, when we perceive distance subjectively, we will tell

(a) Even the recent works pertaining on perception are unmindful of his question, e. g., (1, 2, 5 7, 9, 10, 13, 17, 19, 20 and 21).

(b) If this is the case, the notion 'regression' is inconsistent with the idea of evolutionism. Because it is in urgent need for the organism to discern the distance precisely from itself to an object, say, a prey to catch it in order to survive. It can hardly be conceivable that the 'regression' has began at such an advanced stage of progress as that of the higher animals like mankind.

(c) This word is used in a sense of a mental process, it does not mean 'to project a ray of light' in the physical action. The writer does suppose that the 'projection' itself is nothing but the perception of visual space. The force must be a special energy.

merely our 'feeling'.[d] Accordingly, Sterneck went so far as to estimate the distance to the zenith to be no more than 12 m[22]. On the contrary, the relative discrimination of the perceived distance is considerably accurate. This fact has been testified by the experiment on the 'depth limit' in the first part of this paper.[e] As for the perception of depth in a long range, the 'projected' position of the retinal image decreases in proportion as the real physical distance increases representing a serial reduction of the depth localization, so that the 'depth limit' at length turns up. To make the point clearer, the writer will introduce this problem again in reference to size constancy.

The secondary factors consist of several cues which reinforce the main factors. Among others, the most important cue is the continuity of the surface whose effective condition being heterogeneous and its miscellaneous sections being easily descriminable.[f].

SIZE CONSTANCY AND ITS REPRESENTATIVE THEORIES

In relatively short range of O, a receding ob.ect appears much the same in size in spite of the marked diminution of its retinal image. This phenomenon is called 'size constancy' and studied extensively by numerous psychologists in the field of experimental psychology. As their investigations are dealt with almost exhaustively by many experts in the line,[g] so the writer treats of only special problem which is important and yet is escaping their notice.

Fig. 1 shows Brunswik's diagram explaining size constancy. According to his illustration, $s=OS$ is apparently equal size to $w=O_1W_1$ which is located three times farther than s; and $p=OP$ is the area on the plane SO projected by w. On the basis of this geometrical interpretation he expressed the implication in a formula, $100\frac{s-p}{w-p}$. This interpretation must be correct so far as geometry is concerned, but it is irrational to apply it bodily to the mental process. So, it does not necessarily follow that the size of OW is the same with that of O_1W_1. For the perception of size may vary in pro-

(d) So Gilinsky's formula $s\fallingdotseq\varphi\cdot d$ (s=perception size, φ=visual angle, d=perceived distance) may be applied only in a short range of O.

(e) Cf. The Annual Report of the Gakugei Faculty of the Iwate University Vol. 11(1975) p. 3.

(f) Gibson's miscellaneous gradients or perspective may be effective within relatively short range of O.[9]

(g) Surveying the recent psychological works on the visual space perception, the writer learned that the studies in size constancy made by Brunswik[6], Thouless[23] and Holway & Boring[15] are treated of in common, cf. e. g., (1, 3, 9, 10, 12, 16 and 22). So it is reasonable to regard even now that they are representative of researches on the subject of size constancy.

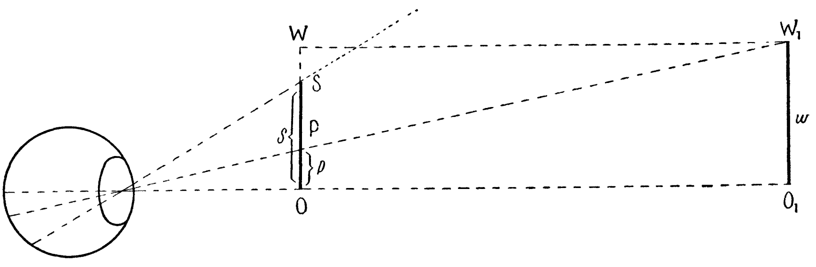


Fig. 1

portion to the distance from O. Accordingly (w−p) may not equal to (OW −p). As for the important character of the length or depth within the short range of O, it will be made clear later.

Inspecting Fig. 1, one can find easily that in order to get the 'complete constancy', w must coincide with s or OW. Then the following contradictions should take place. First, if equal sized stimuli are localized at the same distance from O, their retinal images should be of the equal size, so that both stimuli should appear to be of equal size too. Such a mental process is far from size constancy, for 'size constancy' means that two stimuli are perceived isometric in spite of the size of the retinal images. Some measurements of the experiments applied to Brunswik's formula or its simplified form, s/w, which show 'complete constancy' or the approximate value, seem to be falling into the very same error. Secondly, if both O_1W_1 and OW coincide; then w=s=OW; therefore p=s, and p=w; consequently (s−p)/(w−p)=0. Thus Brunswik's formula implicates evident contradiction. For in case of indicating 'complete constancy', it shows, on the other hand, no constancy.

Upon Thouless' logarithmic formula, the similar criticism may be given. Regarding his diagram relating to size constancy, the writer will touch on it in the course of discussion.

Holway and Boring[15] have performed an investigation on size constancy. The standard and comparison stimuli were uniformly illuminated circular light images. The diameter of the former subtended a visual angle of one degree at each position varying from 10 to 120 feet. The latter was 10 feet from O. O's task was to compare two stimuli adjusting the latter in diameter so as to appear to be of the same size as the former. They (the authors) showed both the 'law of size constancy' and the 'law of the visual angle' by a diagram represented in Fig. 2. The writer doubts whether the oblique line really represent the law of size constancy. As the dimensions subtending a certain angle will gradually increase in conformity to the

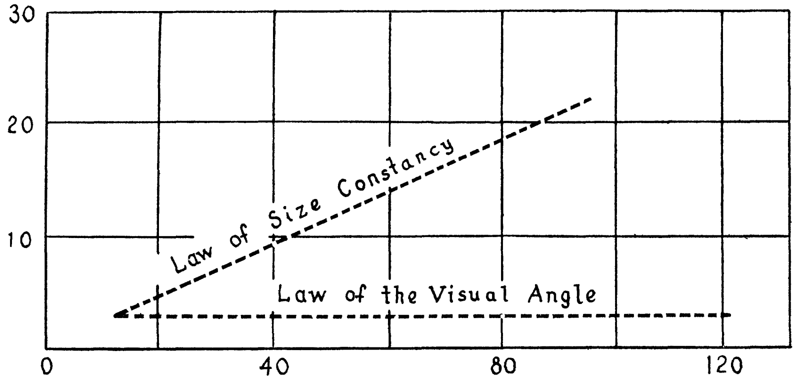


Fig. 2

extension of distance. So the claviform of the line must be caused by the special quality of the stimulus (standard stimulus), not by the intrinsic nature of size constancy. Objects of several distances subtending equal visual angles throw the equal sized images on the retina, accordingly, in this sense, the oblique line should stand for the 'law of the visual angle'. But, if the 'law of the visual angle' means "accommodated objects which subtend equal visual angles are equal apparent size", one should think of the fact that such a 'law of the visual angle' may be effective only at the distance beyond the 'depth limit', as will be alluded later.

The size constancy means, as mentioned before, such a perception as a receding object appears much the same in spite of the diminution of its retinal image, that is, despite the increase of the distance of the object from O. So it seems to the writer that the pallalel line to the axis of abscissa ought to be of the 'law of size constancy'.

The writer, on trial, dealing with one of the results of their experiment (Table 1), got, for convenience's sake, the mean value of Ss and Sc, taking the average of 5 Os (strictly, 3-5 Os), at distances, 10, 20, 40, 60, 80, 100, and 120 feet. The results of computation are shown in Table 1.

Table 1 Results of Computation Taking Average of 5 Os.

Ds	10	20	40	60	80	100	120
Ss	2.2	4.4	8.8	13.2	17.6	22.0	26.4
Sc	2.2	4.7	9.3	13.5	17.7	23.5	24.8
Sc/Ss	1.0	1.1	1.1	1.0	1.0	1.1	0.9

Ds=distance (ft.) from O to standard stimulus. Ss=diameter (in.) of the standard stimulus in each distance. Sc=diameter (in.) of the comparison stimulus equated in perceived size to standard stimulus. Sc/Ss=ratio of Sc to Ss.

to Ss.

Scrutinize this table especially the ratio of Sc to Ss, and one can easily find that this ratio resembles closely to Brunswik's simplified formula, s/w, showing that Sc is exactly in accord with Ss, i.e. the objective physical size.

NEW TENTATIVE THEORY OF SIZE CONSTANCY

So far, as adequate theory for the size constancy has not been formulated yet, the writer advances tentatively a new theory. Upon the strength of the triplicate functions, namely, accommodation, convergence, and binocular disparity which are also dependent on the complex visual organ consisting of the anatomical, physiological, and psychological mechanisms.

As mentioned before, we *project* or localize the retinal image at the position coinciding with that of the physical existence from whence the stimulus springs. Especially within the very short range of O, mathematical formulas, particularly, those of geometry may be applied rather rigorously.[h] The process that the retinal image is *projected* outward according to the distance-variables may be illustrated in Fig. 3.

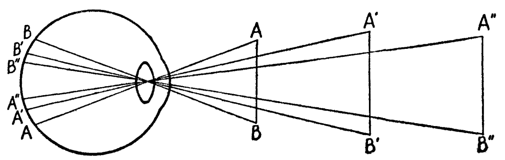
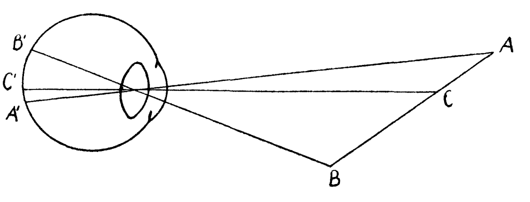


Fig. 3

In Fig. 3 the retinal image BA is *projected* outside at AB, the *very* position occupied by a physical existence from whence the light rays have sprung; the same is to be applicable to the following cases: the relation between B'A' and A'B', B"A" and A"B", supposing that AB has receded to the position of A'B' or A"B". Consequently, **though the size of the visual images or visual angles are diverse markedly, the perception of**

(h) Cf. (20).

(i) This explanation is applicable to the shape constancy, as illustrated below. Provided that B'A' is the visual image of a tilted disk AB, point A' is 'projected' at A, the position of the source of the stimulus, B' at B, C' at C, etc. If the distance increases, such a procsss cannot be carried out, so the perception of the shape will be an ellipse (Cf. the next paragraph).



the size of objects is almost equal.[i] *This must be the essential quality of 'size constancy'.*

As the depth or the distance from O increases, the localization of the *projection* is gradually becoming compressed till at length the 'depth limit' appears. This process can be shown in Fig. 4.

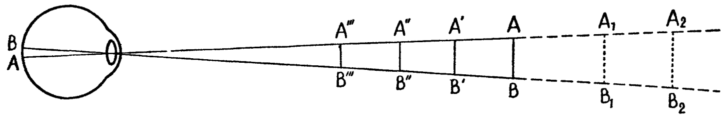
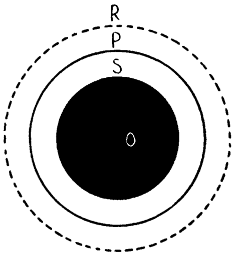


Fig. 4

AB means a stimulus, the source of the retinal image which is to be 'projected' according to the conditions. *If AB is of very short distance from O, the retinal image may be 'projected' to the very position of AB as explained above; but if the distance of AB increases in a certain degree the image may be 'projected' at $A'B'$, a compressed position; and if the distance still more extend, the 'projection' may be at the more compressed position of* $A''B''$ and so on[j]. Therefore, the percept appears smaller and smaller in proportion as the distance increases. By the way, assuming that AB is the 'depth limit', the stimulus beyond it subtending the equal visual angles, e.g., A_1B_1, A_2B_2 or A_3B_3, may all be *projected* at AB. That is the reason why the size of the sun or the moon, or the shape of the sky etc. is determined as expounded in the first part of this paper.

This theory was sufficiently proved by one of the exmaples provided by an experiment on chickens conducted by Götz[12], or one on human infants by Frank[8]. Chicks only three months old trained to peck at the bigger one of two simultaneously presented grains, chose in critical experiments the bigger yet farther lying grain whose retinal image was only 1/30 of the smaller. The proportion of the size of the grains were 4 : 5, the smaller was 15cm. while the bigger was 73 cm. distant from the chicks. At greater distances, however, they did peck at the smaller one.

(j) Thouless' illustration[23] showed below may be easily explained by this exposition. I. e. R = stimulus. S = retinal image. P = projected or localized position. S is, however, too large, it must be expressed by the visual angle made by R. The notion 'the character given by peripheral stimulation' or 'the stimulus character' is ambiguous.



The human infants seem to show a more remarkable constancy of size. Above all an infant of twenty months selected as the bigger one a box whose retinal image was only 1/300 of the size of the smaller and nearer box which correspond to a liner proportion of 1 : 18. The proportion of the boxes were 6 : 8, the bigger being placed 6 m. distant from the infant, whereas the smaller only 25 cm. distant.

The process of the 'size constancy' may be verified fully also by photographs taken at a close range. Fig. 5 represents a photograph taken at the distance of 1.0 m. The retinal image of the original, when we see the latter

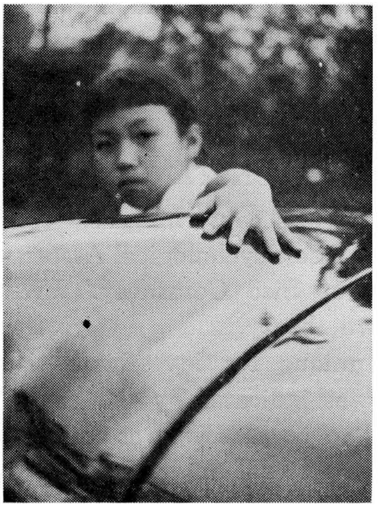


Fig. 5

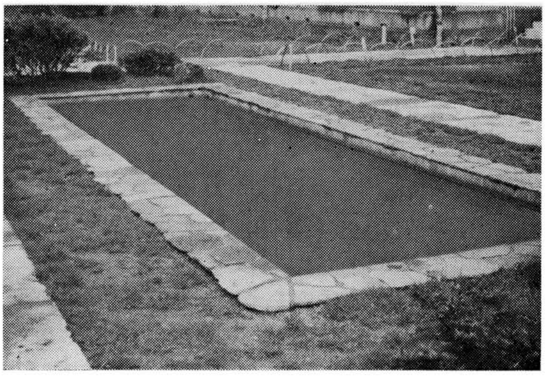


Fig. 6

at the same distance where it was photographed, must be quite the same as the picture of the photograph. The reason why the picture appears so disproportional may be that every part of the original must be projected on the plate or the retina according to the physical laws of light rays. The magnified part of the retinal image, i.e. the hand may be *projected*, when we see an original, at the distance of 1.0 m., i.e. the nearer part of the original, but the lower extremities may be *projected* say, 2 m. and over, so that in our perception the figure or the form, unlike the photograph, is well proportioned. Anyone will find out that a photograph taken at a relatively short range, e.g. that of a room, a garden, a swimming pool, or a baseball ground etc. appears far beyond the original as illustated in Fig. 6. In it the size of the pond is only 2.0×7.5 m. size. The reason may be as follows. In the photo, the foremost part comes out most magnified, then tapering off gradually, the last part of it diminishing remarkably. On a natural observation, a scene similar to the very picture of the photo having such a proportion of the foremost part to the last is really a very large scene as a matter of course. So we would turn the picture of a photo into a directly seen view and would become possessed with an illusion to substitute the former for the latter. In general, unlike animate things inanimate objects become grandeur instead of deformed through the partial magnification.

On the other hand, in a photograph of a distant high mountain, the depth or distance from O is compressed such an extent that when the photo is turned into a directly seen view, the mountain may be localized, in general, remarkably ahead of the 'depth limit', so that the distant mountain in a photo appears not so high as that seen directly which is *projected* at the 'depth limit'. Supposing that the latter is AB in Fig. 4, the former may be A″B″ or A‴B‴[k]

WRITER'S OWN EXPERIMENTS ON SIZE CONSTANCY

The writer once published an experimental results concerning size constancy at the Sixth General Meeting of the Japanese Psychological Association in 1937, on the subject of 'Intrinsic Nature of Size Constancy.' Even now he has confidence in the validity of his own theory.

The arrangement of the experiment was unique for investigate size constancy, because the degree of the constancy was indicated by the 'range' in which the apparent size of the stimulus was to be perceived as constant independent of the size of the retinal image or the visual angle.

The experiment was performed by day within a room, in 1937. The apparatus employed were a pair of white cardboard disks of 7.5 cm. diameter; measurements at 10 m distance, a pair of disks of 15 cm. diameter were used. The experiment measured apparent size at distances varying from 25 cm. up to 10 cm. O's task was to match the comparison stimulus to the standard stimulus with binocular regard. E regulated the size of the comparison stimulus which was first at the same position which the standard stimulus fixed at a certain distance from O, by varying the position or distance from O nearer and nearer until it perceived larger than the standard (vo′), and then varying the former farther away until it appeared smaller than the latter (vu′). The aggregate, vo′+vu′, was regarded as the range of size constancy

(k) It seems to be ambiguous and inadequate to explain such a phenomenon as "phenomenal compromise", or "compensation of perceived size with respect to perceived distance"[24] And besides, as the perception by the photograph is considerably differ from the 'direct' perception explained above, so it may not be adequate to make experiments on perception especially depth by means of photographs. This fact seems to have been proved by the test made by Weinstein.[25]

at a certain distance from O. As for vo″ and vu″, they are disregarded because of its low numerical value in view of the result of the experiment.

The present experiment was studied under two sets of conditions: (1) measured in the place where spatial continuum and other cues were to be seen, i. e. factors which can suggest the physical distance from O to the stimulus were clearly observed; (2) measured under the special conditions designed to eliminate the spatial continuum, i.e. the size of the retinal image may be the only determiner of the apparent size. The 'range' of size constancy was found whose magnitude or length being a function of its distance from O. The results for two sets of conditions are presented in Table 2.

Table 2. Extend of Each Range of Size Constancy Depending on Distance-variables.

S	P \ D	25 cm	50 cm	1 m	2 m	3 m	5 m	10 m
	vo′		14. 4 cm	17. 5 cm	18. 7 cm	24. 7 cm	20. 1 cm	28. 5 cm
I	vu′	24. 1	19. 6	15. 9	19. 0	25. 1	17. 8	26. 8
	sum	24. 1	34. 0	33. 4	37. 7	49. 8	37. 9	55. 3
	vo′		14. 4	16. 5	21. 1	19. 9	19. 5	18. 7
II	vu′	30. 0	20. 9	27. 4	21. 0	22. 0	18. 1	20. 9
	sum	30. 0	35. 3	43. 9	42. 1	41. 9	37. 6	39. 6

S=each set of studies. D=distance from O to the standard stimulus.
P=each procedure. sum=sum total, that is the scope of each range of size constancy.

The data denote the mean valuation of five Os. For each O eight measurements were made by changing places of standard and comparison stimulus. In the case of II, except measurements 1-3 m, the data of every distance were the mean valuation of 4 Os. To get vo′ out of the observations at 25 cm. distance from the point of view was actually impossible owing to too short distance from O. Therefore, the range of constancy of 25 cm. is really larger than the numerical value in the table. The results of both I and II appear almost the same except those of 10 m. measurements. It seems that if the depth or the distance from O to the stimulus attains so much length of 10 m. or more, a spatial continuum begins to play its part. In a general way, each 'range' of size constancy is almost the same in spite of the distance from O. But once the size of the retinal image or the visual angle in each 'range' of constancy is noticed, the problem assumes quite another aspect.

Table 3 represents the ratio of the physical sizes of the visual images *projected* from both extremities of each 'range' of size constancy. The data indicate the *ratio of* the assessed size of the smaller visual image localized

Table 3. Ratio of Area and Diameter of Retinal Image in (Each Range of Constancy.)

S	M \ D	25 cm	50 cm	1 m	2 m	3 m	5 m	10 m
I	diam.	.51	.51	.71	.83	.85	.93	.95
	area	.26	.26	.50	.69	.72	.86	.90
II	diam.	.45	.50	.66	.81	.87	.93	.96
	area	.20	.25	.44	.66	.76	.86	.92

M = each set of magnitudes. diam. = diameter.

at the farther extremity of each range *to* the larger visual image at the nearer extremity of each range taking the latter as 1. It is necessary to scrutinize these data for the appreciation of the characteristic of 'size constancy'. As a case in point the data concerning 'size constancy' of the area are shown graphically in Fig. 7.

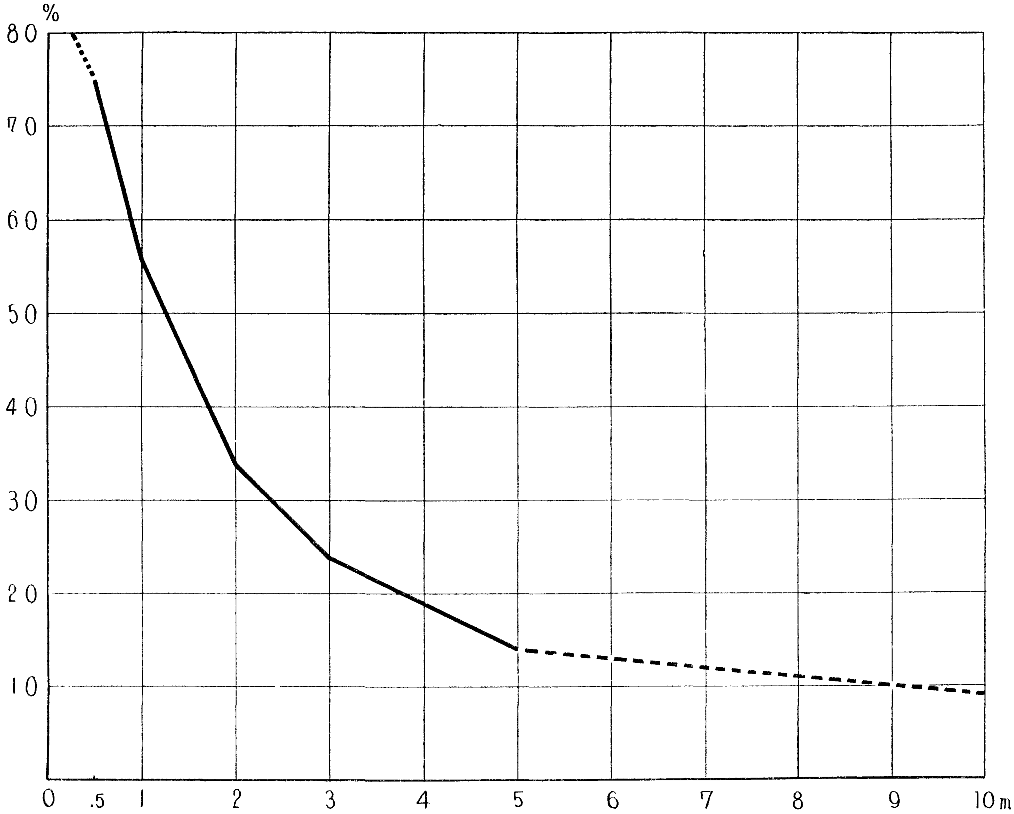


Fig. 7. Size constancy pertaining to the area of the comparison stimulus.

In Fig. 7, the co-ordinate is expressed in linear units. The abscissa gives the distances from O to the standard stimulus or the distances of *projection* of the retinal image (m.). The ordinate the percentage of decrease of the area which shows the limit of the 'range' of constancy. Or otherwise expressed, e. g. at 36cm. (50-14cm.) distance, the decrease of the area cannot become perceived till it loses its 75%. *The 'curve of size constancy' thus falls presipitously in the very short range of O, and then lowers gradually till it joins with the parallel line of the abscissa.* **This characteristic must be the 'law of size constancy' in the strict sense of the word.** In passing, in case of a receding object is perceived, the standard stimulus may be a vague memory image, so the range or the degree of size constancy must be great.

The writer conducted one more experiment connected with size constancy in the open air whose results were reported at the Eighth General Meeting of the Japanese Psychological Association in 1939 on the subject of 'Intrinsic Nature of Size Constancy II'. The experiment consisted of two parts.

In Part I, the apparatus used were a pair of white wooden disks of one meter diameter, for the observation of 50 m. distance only, a pair of disks of 40 cm. diameter were used. The subjects employed were 7 persons. The distances from O to the standard were varied from 50 to 500 m.

The procedures were similar to the previous experiment (cf. p. 10). The results are presented in Table 4.

Table 4. Results of Size Constancy in Great Distance.

Ds	50 m	100 m	200 m	300 m	400 m	500 m
Rs	4. 6	8. 3	16. 5	24. 7	34. 2	39. 8
%	9. 2	8. 3	8. 3	8. 2	8. 6	8. 0

Ds=distance from O to the standard stimulus. Rs=each range or extent of size constancy (vo'+vu') in each distance. %=difference threshold of the perception of size in each distance showing constant.

In view of these results, the cue of the perception of size seems to be mainly the size of the rètinal image. To substantiate this fact, experiment Part II was carried out.

Part II: The appratus used consisted of a series of 13 disks ranging in size from 0.94 to 1.06 m. in diameter, in 1 cm. steps (the series of sizes will be applied correspondingly to the smaller disks centering around 40 cm). The subjects and distances were quite the same as Part I. But the procedure differs. In this experiment the comparison stimulus was shifted gradually from the same size of the standard stimulus to the larger ones (vo′), or to the smaller (vu′) in each distance from 50 to 500 m. The results, that is, the difference threshold of the perception of size in each distance were quite the same as those of Part I, as showed below.

Ds	50m	100m	200m	300m	400m	500m
%	8.4	8.6	8.0	7.6	8.0	8.2

The difference threshold or differential limen obtained from the present experiment means if *the size of the retinal image does increase or decrease beyond a certain degree, the difference of size may be perceived.* This is nothing but Weber's law.

DISCUSSION

It will become clear that *the phenomenal facts called size constancy have several different aspects.* The writer can enumerate three aspects of it. First, the 'intrinsic' size constancy or size constancy proper, which means perception of isometric of two or more stimuli in despite of the size of their retinal image. Hold your hand at 20 cm. distanse before your eyes and then remove it at 60 cm. distance, and you will find that the receding does not arouse the perception of a decrease of size of your hand but arouse that of a recession. The ratio of the size of your hand in the latter case to that in the former is 9:1. Secondly, the case obeying Weber's law was explained just now. Thirdly, the size constancy which indicates that the size of stimuli which subtend the equal angles will be perceived of equal size may be only applied to very remote stimuli beyond the 'depth limit'. *This phenomenal fact must be the 'law of visual angle'.* These three instances have a special feature respectively, which has escaped and is escaping psychologists' notice. In brief, in the very short range of O, the 'law of size constancy' takes effect, then, in the intermediate range, Weber's law comes into force, and lastly in the great distance from O, the 'law of visual angle' becomes operative. The writer thinks only the first, the substantial size constancy, ought to be called 'size constancy.'

That the visual organ is none other than a 'projecting mechanism' may be proved fully by a several phenomenal facts. *One of the facts to verify for certain the psychical 'projection theory' is a phenomenon referred to as Emmert's law.* When an after-image is 'projected' outside, its localization is indefinite generally with respect to size and distance. They are entirely conditioned on the back ground as William James stated: "Produce an after-image of the sun and look at your fingertip: it will be smaller than your nail. Project it on the table, and it will be as big as a strawberry; on the wall as large as a plate." So far, so good, but he went so excessive length as to exaggerate out of proportion: "on yonder mountain, bigger than a house"(14). The *projection* may be a matter of energy, so viewed from a certain angle, an after-image of the sun which is of feeble energy will be *projected* relatively at a short range, and cannot be *projected* on "yonder mountain". Therefore the size of the after-image cannot become bigger than the percept of the sun which is of an intense energy and *projected* on the 'depth limit'. Accordingly, it is unreasonable that the after-image becomes bigger than the house. *The projection of after-images is a broad fact that is but one facet of the 'projecting force' which is the basis of the fundamental visual space perception.* It is quite incomprehensible to the writer that such an essential feature of the space perception has been passing entirely unnoticed.

In the next place, muscae volitantes (flitting flies), that is, specks seen floating in the vitreous fumor are visible before the eyes. These floating specks are nothing else than a physiological process, but they are perceived in the external visual space being *projected* outside of the body. And further, eidetic imagery and stereoscopic vision etc. *are all revealing the 'projecting function' of the visual organ.*

The projection or the localization is to be carried out abiding by the three laws mentioned above, but it violates them now and again. For instance, one mistakes a little mosquito closely before one's eyes for a bird *projecting* far off the visual image of the mosquito into a certain distant space, and conversely. Some persons, though seldom, have a tendency to perceive distant big things, especially those outside of the 'depth limit', e.g. heavenly bodies, far larger than the ordinary men do. Perhaps that is because they *project* the stimuli far beyond the 'depth limit' of ordinary men.

Bergson expounded his views: "There is not, in fact, an unextended image which forms itself in consciousness and then projects itself into P. The truth is that the point P, the rays which it emits, the retina and the nervous elements effected, form a single whole; that the luminous point P is a part of this whole; and that it is really in P, and not elsewhere, that the image of P is formed and perceived."(4)

The idea that the luminous point P is a part of the whole is really for-sighted, but Bergson himself was not free from confounding the physical world with the psychological world, namely, the material existance with the percept. Assuming that the point P, the source of the visual image on the retina, is a star several hundred light years away, one cannot perceive it at such an extraordinary point, it must be perceived at the 'depth limit.' But if P is in the scope of the 'law of size constancy', the retinal image of it will be *projected* at the same position of the source of stimuli. Therefore, Bergson's statement is fit exactly for the very short range of us. He stood on a 'dualistic' stand point also, so far as the visual space perception is concerned.

CONCLUSION

We construct our visual world by means of a quite original way, *projecting* retinal images outside according to the laws or principles. In the very close range of us, as alluded before, where the physical existences are situated very close to us, we *project* our retinal images outward so as to coincide with the sources of stimuli or physical existences following the *law of size constancy* gradually contructing their localizing positions in proportion as the distance increases, until this *law of size constancy is superseded by Weber's law*. The compression of localization progresses at an increasing tempo till at last 'depth limit' presents itself. *Outside of it all stimuli are to obey the 'law of visual angle'*. Thus our visual world is altogether unique being entirely different from the physical world which is only the source of the former. Surely, as Bergson advocated, the ego and the visual world form a single whole. It may be apt for the term *'self'* to mean not only the 'self' but the visual world perceived by the 'self' as the center. This *single whole* ought to be entitled the PSYCHOLOGICAL EGO.

SUMMARY

In the first part of this paper, the writer elucidated that the perception of distance has its limitation. This limitation named 'depth limit' plays a very important part in the visual space perception. By means of this 'depth limit' many phenomena in the visual space, e.g., the moon-illusion, the forms of starry, the blue, and the clouded skies; the phenomena that a far and large mountain is perceived as a nearer and smaller one in the clear air, or a fire at night appears very near etc., are explained systematically and consistently.

In the present paper, the writer has aimed at clearing up the cause of that mental process, the 'depth limit'. He presumed by the data obtained from experimental studies that the fundamental function of the visual organ must be a *projecting mechanism* (in a sense of a mental process), which is acting according to a certain laws or principles. This mental action called 'size constancy' has, in general, three phases. First, in very close range of O, the retinal image will be *projected* at the same position of the physical

existence, the source of the stimulus, irrespective of its distances. Accordingly, the perception of size does become constant, though the sizes of the retinal images are diverse in proportion to the distances of the stimulus. This process may be called *law of size constancy* in the strict sense of the word; secondly, in the next intermediate range, 'size constancy' follows *Weber's law*. That is to say, if the size of the retinal image does increase or decrease beyond a certain degree, the difference of size may be perceived; thirdly, in the range over the 'depth limit', the 'size constancy' submits to the law of *visual angle*, namely, stimuli beyond the 'depth limit' are to be perceived at the 'depth limit', so that all stimuli which correspond to the equal visual angles may be perceived of the same size.

Thus the miscellaneous phenomena in the visual space may be expounded reasonably and systematically.

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RÉSUMÉ

Dans la première partie de cette thèse, l'auteur a élucidé que la perception de la distance a sa limitation appelée 'la limite de la profondeur' qui joue une partie très importante à la perception visuelle de l'éspace. Au moyen de 'la limite de la profondeur' nous pouvens expliquer systématiquement et compatiblement plusieurs phénomènes dans l'éspace visuel, c'est-à-dire, l'illusion de la lune, les formes des cieux nuageux, bleux ou avec les étoiles; le phénomène que nous percevons une montange large et distante dans l'air clair plus petite et plus prochaine, ou qu'un incendie dans la nuit apparaît très prochain.

Dans cette thèse, l'auteur se propose comme but d'éclaircir des questions sur le processus mental, 'la limite de la profondeur'. Par toutes les données obtenues des études expérimentales, il présume que la fonction fondamentale de l'organe de la vue doit être un *mecanisme projectif* (dans un sens d'un processus mental) qui agit suivant des ou certaines lois ou principes. Cette action mentale est appelée la constance de la grandeur et en génèral, a trois phases.

En premièr lieu, dans la sphère très proche de l'O, l'image rétinaire sera *projeté* à la même position de l'existance physique, la source du stimulant. Par consèquent, la perception de la grandeur devient constante, bien que les grandeurs des images rétinaires soient diverses par proportion des distances des stimulants. Ce processus est peut-être appelé le loi de la constance de la grandeur au sens rigoureux de ce mot.

Secondement, dans la sphère intermediaire, 'la constance de la grandeur' se conforme à la loi de Weber. C'est-à-dire, si la grandeur de l'image rétinaire augmente ou diminue, au delà d'un certain degré la différence de la grandeur pout être perceptible.

Troisièmement, dans la sphère qui est au dessus de 'la limite de la profondeur', 'la constance de la grandeur' soumet à la loi de l'angle de la vue, autrement dit, nous devons percevoir le stimulant au dessus de la limite de la profondeur à la limite de la profondeur; en conséquence, nous pouvons percevoir tous les stimulants, qui correspondent au même angle de

la vue, à la même grandeur.

Ainsi les phénomènes de toutes espèces dans les espaces visuels peuvent être exposés raisonnablement et systématiquement.

ZUSAMMENFASSUNG

Im ersten Teil dieser Abhandlung stellte es sich heraus, dass die Wahrnehmung der Distanz ihre Limitation hat. Diese 'Grenze der Tiefe' genannte Limitation spielt in der Wahrnehmung des visuellen Raumes eine sehr wichtige Rolle.

Durch diese 'Grenze der Tiefe' viele Phänomene im visuellen Raum,wie z.B. die Mond-Illusion, die Formen des gestirnten, blauen oder wolkigen Himmels, die Phänomene, wie in der klaren Luft ein weit entfernter grosser Berg als ein näherer und kleinerer wahrgenommen wird, oder in der Nacht ein Feuer uns sehr nahe erscheint etc., wurden systematisch und konsequent erklärt.

In dieser Abhandlung haben wir versucht, die Ursache des seelischen Prozesses, der 'Grenze der Tiefe' in klarer Weise darzulegen. Infolge der von experimentellen Untersuchungen gewonnenen Daten, wurde es angenommen, dass die fundamentale Funktion des visuellen Organs ein *projizierender Mechanismus* (im Sinne eines seelischen Prozesses) sein müsse, die nach gewissen Gesetzen oder Prinzipien wirke. Diese Grössenkonstanz genannte seelische Aktion hat, im allgemeinen, drei Phasen.

Erstens, in sehr nahem Gebiet vom Betrachter, wird das Netzhaut-bild an derselben Stellung der physikalischen Existenz, der Quelle des Reizes *projiziert* werden. Infolgedessen wird die Perzeption der Grösse konstant, obgleich die Grösse der Netzhaut-bilder im Verhältnis zu der Distanz des Reizes verschieden ist. Dieses Gesetz mag als das 'Gesetz der Grössenkonstanz' im strengen Sinne des Wortes bezeichnet werden.

Zweitens, im mittleren Gebiet, folgt die 'Grössenkonstanz' Weberschem Gesetz. Mit anderen Worten: wenn die Grösse des Netzhaut-bildes über einen gewissen Grad hinaus zunimmt oder abnimmt, so mag die Differenz der Grösse wahrgenommen werden.

Drittens, im Gebiet, das die 'Grenze der Tiefe' überschreitet, folgt die 'Grössenkonstanz' dem Gesetz des Sehwinkels, d.h. Reize, die über die 'Grenze der Tiefe' hinausgehen, können an der 'Grenze der Tiefe' wahrgenommen werden, so dass alle Reize, die dem gleichen Sehwinkel entsprechen, mag als dieselbe Grösse wahrgenommen werden.

Also mögen die mannigfaltigen Phänomene im visuellen Raum vernünftigerweise und systematisch ausgelegt werden.